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RADIO POLE OF THE GALAXY AT 205 Mc.

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ABSTRACT

The pole of the galaxy was determined from measurements of galactic radiation at a frequency of 205 megacycles. The radiation is highly concentrated along a small circle close to the galactic equator. The coordinates of the pole are $266^{\circ}.8 \pm 4^{\circ}.5$ galactic longitude $87^{\circ}.43 \pm 0^{\circ}.34$ north galactic latitude. The small circle has a north polar distance of $91^{\circ}17' \pm 11'$. The relative intensity and approximate half width of the galaxy as a function of galactic longitude are presented. The experiment and certain consequences of the results are discussed.

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SECTION I - INTRODUCTION

Now that the phenomenon of radio frequency radiation from the galaxy is well-known and its potential usefulness as an additional tool for analysis of the structure of the galaxy is coming to be recognized, it is desirable to have precise information concerning the nature of the distribution of galactic radio frequency radiation both in direction and with respect to frequency. The ideal goal in this regard would be a complete specification of the function $I_\nu(l,b)$, the specific intensity as function of frequency and galactic longitude and latitude, together with a quantitative statement of its statistical characteristics if it is found to vary in time. The present state of our knowledge of galactic radiation, of course, falls far short of this goal. Several preliminary surveys of the approximate distribution of galactic radiation at frequencies between 20.5 Mc per second and 480 Mc per second have been published.[1]

The lack of detailed information of high accuracy is ascribable to the fact that investigations of galactic radiation in the radio frequency spectrum are at least as complicated and as difficult as those problems more familiar to astronomers concerned with absolute spectrophotometry in the optical region of the spectrum. There is, in fact, an added difficulty which must be overcome in making measures of specific intensity in the radio frequency region of the spectrum, because the resolution of the antennas of present

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1 Numbers refer to reference list.

radio telescopes is of necessity of the same order of magnitude as the dimensions of the radiating regions in the galaxy. Because of this restriction the accurate determination of the actual distribution of specific intensity as a function of direction presents a problem which is certainly of a high order of complexity and perhaps not even uniquely solvable in principle.

As a result of this state of affairs, it is necessary, as in more conventional branches of astronomy, for the observer to proceed slowly. He must frame precise observational problems with reference both to their astrophysical importance and to their suitability for observations with radio telescopes. One such problem deals with the quantitative determination of how well the galactic radiation agrees with generally accepted ideas of the position of the galactic plane. Until now, only one such quantitative determination was available. It made use of data obtained by Reber at 160 Mc and also at 480 Mc. Reductions of these data indicated a high order of internal consistency.[2] Aside from the fact that the data from which these computations were made were gathered purely as a preliminary survey, and hence might possibly contain systematic errors of direction as great as 1°, there is the fact that the galactic radiation at each frequency must be considered separately. Hence, the present investigation at a frequency of 205 Mc per second is relevant.

At first glance it may seem somewhat surprising that a radio telescope with a comparatively broad antenna pattern could be used for the successful determination of the centroid of galactic radiation. Actually, it turns out the important factors are not so much the dimensions of the antenna pattern, but are the stability of the receiver and amplifier circuits and the accuracy of the geometrical motions for pointing the antenna in different directions. In this connection it is pertinent to remember that military and other installations have often made quite successful use of antennas with broad acceptance patterns for the purpose of radio direction finding.

Galactic radiation appears to arrive chiefly from a band a number of degrees wide near the galactic equator. The specific problem set for solution in this paper is to determine the centroid (that is, the mean galactic latitude) of the 205 Mc galactic signal at all galactic longitudes accessible from the latitude of the observing station, and to find the optimum small circle on the celestial sphere best fitting these observations. This small circle may be characterized by three parameters, l' and b' the galactic coordinates of the north pole of the small circle, and θ the north polar distance of the small circle from the pole characterized by l' and b'.

A number of months of testing the radio telescope used in the present investigation showed the moment to moment stability of the 205 Mc receiving equipment to be reliable to a small fraction of the maximum galactic signal, approximately one percent. In order to utilize fully this high degree of stability of the electrical equipment it was found necessary to attempt to have all angular displacement of the moving parts of the radio telescope reproduceable and accurate to approximately 1/10 of a degree. An effort was made at all points in the design of the observational program and the plan of computing procedure to guard this accuracy.

SECTION 2 EQUIPMENT

The antenna used for these observations was a forty-eight dipole array, constructed by placing two SCR-268 azimuth receiving mattresses side by side. This seventeen foot square antenna was mounted on an alt-azimuth mechanism so as to provide vertical polarization with respect to the horizon. Direct reading azimuth and elevation dials were installed and the relationship of the major axis of the antenna pattern to true north and the local vertical was determined as a function of the dial indications.

Besides routine ground level measurements of the antenna pattern, careful checks of the high elevation angle pattern were made using the quiet sun as a source, at a time when the sun was well away from any strong galactic source of radio frequency radiation. Thus, it was determined that this array possessed a pattern $15^\circ \times 15^\circ \pm 0.5^\circ$ away from the ground, and that the pattern of the main lobe was symmetric to better than 0.25°. Furthermore, as a result of sweep measures on the quiet sun, it was found that the entire antenna and mount could be pointed by direct reading of the dials to a precision of better than $\pm 0.2^\circ$ for elevation angles greater than 8°.

Table 1 shows a typical set of measurements of the position of the sun. Azimuth sweeps were made on a day when the sun was quiet. If a burst occurred during a sweep, the sweep was discarded. The sweeps were made in closely timed pairs in opposite directions. The azimuth of the sun was measured by averaging several pairs of equal amplitude points on each peak and taking the average of these as azimuth of the maximum of the peak. An average azimuth was found for each pair of + and - sweeps.

The GCT of each peak was measured from the tape. A graph of the azimuth of the sun vs. EST was made from data in the nautical almanac and the tables of U. S. Hydrographic Office publication 214. The position of the sun at the time of each peak and the average position of the sun for each pair of sweeps was found.

The first order side lobes were found to be down 16 decibels below the main lobe. While the entire minor lobe structure was not the most desirable, a number of cross checks were made to ascertain that no important signals were arriving from directions other than those subtended by the main antenna lobe.

The entire antenna mechanism was mounted on a platform provided with leveling adjustments and with a level whose least count was 0.08°. Azimuthal rotation was obtained from an induction motor and gear assembly of sufficient torque that only large gusts of wind made even momentarily noticeable variations in the rate of rotation. The position of the antenna in azimuth was inserted on the records automatically by using a carefully adjusted toothed wheel and switch assembly attached to the vertical column drive unit.

The receiver used in these measurements was the first one built by this group especially for the reception of galactic and

TABLE I

COMPARISON OF OBSERVED AND CALCULATED AZIMUTH OF THE SUN

Sweep Direction	Calculated Azimuth of Sun	Measured Azimuth of Sun	Difference
+	119°.5	119°.4	
-	119.8	119.2	
mean	119.6	119.3	+ 0°.3
+	120.5	120.4	
-	120.7	120.3	
mean	120.6	120.4	+ 0.2
+	122.3	122.7	
-	122.5	122.5	
mean	122.4	122.6	- 0.2
+	123.5	123.8	
-	123.7	123.5	
mean	123.6	123.6	0.0
+	124.7	125.0	
-	124.9	124.9	
mean	124.8	125.0	- 0.2
+	127.0	127.2	
-	127.2	127.0	
mean	127.1	127.1	0.0
+	128.9	129.4	
-	129.2	129.0	
mean	129.0	129.2	- 0.2
+	131.7	131.9	
-	132.0	131.5	
mean	131.9	131.7	+ 0.2
+	133.3	133.5	
-	133.5	133.4	
mean	133.4	133.4	0.0
+	135.2	135.5	
-	135.6	135.3	
mean	135.4	135.4	0.0

solar noise. This receiver was a normal superheterodyne, but considerable effort had been expended towards producing a physically and electrically stable unit.

The receiver had a bandwidth of 4.5 Mc $\pm$ 1/2 Mc centered at 205 Mc $\pm$ 1 Mc. The time constant of the Esterline-Angus recording milliammeter was approximately three-eighths of a second. The stability was generally such that amplitude variations in the record greater than one part in two thousand of the internal receiver noise could be definitely ascribed to variations in the energy received by the antenna.

SECTION 3 OBSERVATION PROCEDURE

The general observing plan was to sweep the antenna 360° in azimuth when the galactic equator passed through the zenith. Thus, the path of the center of the antenna beam would cross normal to the galactic equator, minimizing the labor of reducing the computations and also reducing the effect of asymmetry of a local galactic source on the position of the apparent centroids.

The details of the observing program were worked out as a compromise among a number of conflicting factors. The sun was nearing a position which would prohibit for several months the observation of the milky way available at Ithaca (Lat. $42^{\circ}\ 29^{m}.3$ north, Long. $5^{h}\ 05^{m}\ 48^{s}.6$), and a large number of positions of maxima would be required for a satisfactory determination of the galactic pole. Ideally, however, only two gauges (sweeps) should be performed in a twenty-four hour interval, and these at the times when the galactic equator passed through the zenith. This would preserve a maximum of pointing accuracy. Finally, the time constant of the recording milliammeter (averaging about three-eighths of a second) made a slow rate of azimuthal rotation desirable.

The observing procedure was as follows:

(1) The dates and periods of observation, with notes on the weather, are shown in Table 2.

TABLE 2

Greenwich Date 1948	Tape No.	GCT Start	GCT Finish	Weather
Oct. 17	0-171	0025	0245	Cloudy
	0-174	0530	0815	Cloudy
18	0-177	0012	0245	Snow, rain,&
	0-179	0530	0838	high winds
19	0-182	0035	0255	Cloudy, cold
	0-184	0530	0805	Cloudy, cold
20	0-187	0000	0235	Rain, heavy
	0-189	0535	0805	clouds
20-21	0-192	2345	0230	Cloudy
21	0-194	0515	0800	

(2) The duration of each 360° azimuthal gauge was approximately six minutes.

(3) The sense of rotation was opposite for consecutive gauges. The intention was to produce a number of pairs of gauges of opposite sense, but of approximately the same celestial path, thus minimizing the effect of the time constant of the recording pen.

(4) Gauges were made in steps of 4° of elevation over the range 0° to 64° inclusive. Because of the angular width of the main antenna lobe and the angular width of the galactic radiations, higher elevation gauges were omitted.

(5) The starts of consecutive gauges were spaced by ten minute intervals, allowing the observer about four minutes to perform

necessary adjustments and to record the events.

(6) The alignment of the equipment with the local vertical was checked before and after each two-hour observing period.

(7) The recording tape, driven by a 60-cycle synchronous motor, ran at a rate of 12"/min. to minimize reading errors.

(8) Time marks accurate to a fraction of a second were placed on the record by means of a chronograph pen on the margin. This pen was controlled by the operator who listened, at appropriate times, to the standard time transmission of radio station WWV.

(9) A mark was automatically placed on the record for every three degrees of rotation, starting with a mark for true North. One mark was omitted each sixty degrees, and the observer labelled the azimuth by hand to avoid ambiguity and provide a double check.

(10) The receiver was switched from the antenna to the reference noise source for about four minutes after each gauge so as to observe the performance of the electronic equipment.

(11) Except for the few seconds required to make the time marks, the observer was listening to the combined receiver and galactic noise. This greatly minimized the likelihood of mistaking any interfering terrestrial radiation for galactic radiation, and provided an additional important check on the electrical performance of the entire equipment.

SECTION 4 - OBSERVATIONS AND REDUCTIONS

It is well to have in mind the actual nature of the quantity which is measured by a radio telescope before describing in detail the exact procedure of obtaining the desired quantities from the observations. The antenna of the radio telescope may be thought of as a device which, when pointed in a given direction, receives radiation not only from that direction, but also from other directions. Therefore, the power in the transmission line from the antenna to the receiving set is proportional to the weighted means of the specific intensity in the various directions. Setting the problem in spherical coordinates as shown in Figure 1, there are three functions to be considered. First, the specific intensity $I_\nu(\theta', \phi')$. Next, the function $G(\text{H}, \text{I})$ which defines the sensitivity of the antenna in various directions from the central axis of the antenna. Finally, the function $P_\nu(\theta, \phi)$ which gives the power delivered by the antenna to the set for a given direction of pointing of the antenna axis corresponding to θ and ϕ. The equation connecting these three quantities is readily seen to be

$$P_\nu(\theta,\phi) = \int_{\phi'=0}^{2\pi} \int_{\theta'=0}^{\pi} I_\nu(\theta',\phi')\, G(\text{H}, \text{I}) \sin\theta' \, d\theta' \, d\phi' \qquad (4.1)$$

For the particular case considered here, the pole of the coordinate system may be identified with the zenith, and θ, for a given sweep of the antenna, is fixed and equal to the compliment of the altitude of the sweep while ϕ is the azimuth toward which the antenna axis is directed at any moment. Now, equation 4.1 reduces to a function of one single running variable denoted by x. Bearing in mind that both the source and the antenna pattern are of small angular extent and are of the general shape of the normal distribution curve, equation 4.1 may be rewritten in the following simplified manner.

$$P(x) = \int^{\infty} G(x-x') \, S(x') \, dx' \qquad (4.2)$$

In this equation $S(x')$ is the total received power corresponding to a small increment of azimuth. The function $P(x)$ is actually recorded on the tape taken at the time of observation. Thus, it is possible, in principle, to form the quantity $\bar{x}_p$ corresponding to the centroid of the observed power distribution as a function of azimuth. This is given by the following equation.

$$\bar{x}_p = \frac{1}{P} \int_{-\infty}^{\infty} xP(x)dx \qquad (4.3)$$

where

$$P = \int_{-\infty}^{\infty} P(x)dx \qquad (4.4)$$

However, the desired quantity is the centroid of the actual source distribution $\bar{x}_s$ given by

$$\bar{x}_s = \frac{1}{S} \int_{-\infty}^{\infty} xS(x)dx \qquad (4.5)$$

where

$$S = \int_{-\infty}^{\infty} S(x)dx \qquad (4.6)$$

It is possible to show that

$$\bar{x}_p = \bar{x}_s + \bar{x}_g \qquad (4.7)$$

where

$$\bar{x}_g = \frac{1}{G} \int_{-\infty}^{\infty} xG(x)dx \qquad (4.8)$$

and

$$G = \int_{-\infty}^{\infty} G(x)dx$$

It should be noted that (4.7) is independent of any assumption about the form of the functions P, G, and S, and furthermore, that the term $\bar{x}_g$ can be thought of as related to a lack of coicidence of the electrical and geometrical axis of the antenna. From comparison of the observed and computed azimuth of the quiet sun obtained on several different days at a number of different altitudes, it was found experimentally that the quantity $\bar{x}_g$ for the radio telescope used satisfies the following inequality.

$$\bar{x}_g < 0\overset{\circ}{.}2 \qquad (4.10)$$

In view of the negligible nature of this correction, it was not necessary to apply any corrections to the observed azimuth to obtain the true azimuth.

While the observing schedule was intentionally arranged so that the plane of the galactic equator would coincide approximately with a vertical circle in order to minimize certain observational errors and simplify the computations, it still required considerable labor to convert the reading actually obtained on the tapes into the desired quantities for computation. Specifically the desired quantities were the altitude and azimuth of the point corresponding to the centroid of the galactic signal for each crossing of the plane of the galaxy and also the Greenwich Civil Time of this crossing. The following procedure was adopted as a satisfactory approximation for locating the centroid. Several pairs of amplitude points on either side of the maximum were located. The azimuth of each of these points was read to 1/10 of a degree and the average taken to be the position of the centroid. Since the number of pairs of points taken was usually three or more and since they were distributed about the points of maximum slope, it was felt that the median so derived could not differ significantly from the centroid.

Obviously a deviation of the median from the centroid is to be expected only in the case of an assymetrical distribution and the observed distributions were found to be remarkably symmetrical. It was, nevertheless, worthwhile to make an independent investigation of the order of magnitude of the deviation of the median from the centroid for a number of specimen distributions with assymetry characteristics similar to or greater than those observed for the galaxy. In no case were the deviations found to be significant when the azimuth of the centroid had been located by the averaging process mentioned. This median point was marked on the tape and the GCT corresponding to the point of crossing of the centroid was read off to the nearest second. At this stage the data consisted of some 320 azimuths and altitudes of centroids of the galactic signal with the corresponding GCT for each observation. To insure numerical accuracy of these data two independent systematic checks were made.

The next step in the procedure consisted of obtaining galactic latitudes and longitudes for the observed positions of the centroids of the signal. These were computed in the following way: First, the altitude and azimuth of the International Astronomical Union (IAU) galactic poles, precessed to the equinox of date, were computed for each separate observation. From these computations and the observed azimuths and altitudes of the centroids, it was then possible to calculate directly the galactic longitudes and latitudes of the centroid and one further quantity of significance in the calculations. This quantity, ψ, is the angle between the direction of sweep and the galactic equator at the point of crossing. The optimum value for ψ is 90°. But, of course, it was not practical to arrange the observations so that this optimum value was obtained for each individual crossing of the plane of the galaxy.

At this stage of the computations, the observations were represented by a series of galactic latitudes and longitudes representing the galactic latitude of the centroid of the galactic signal for a number of different galactic longitudes. The method of computation followed also made it possible to institute an independent check of the computation by calculating in two different ways a side common to two different spherical triangles. These calculations were made with a calculating machine and tables of natural trigonometric functions and were carried to five decimals in the functions and thousandths of degrees in angle to insure adequate guard figures.

To deal with these data in a conventient manner, normal points were formed by dividing the data into approximately 10° intervals of galactic longitude and, for each group of points thus formed, calculating a mean galactic longitude and a mean galactic latitude. It was felt worthwhile to take account of the fact that not all the observations were of equal value. Matters which were deemed to effect the accuracy of the observations were the overall strength of the galactic signal, the tilt angle ψ, and the general appearance of the tape indicating whether or not external sources of electrical disturbances had been present. In particular it was found that observations made at low altitudes were not reproduceable and hence of dubious value. The scheme followed in weighting the points was the following: All observational points corresponding to strong signals and a good tilt angle were given double weight. Observations made at zero degrees altitude, observations giving evidence by the character of the trace on the tape of being untrustworthy due to external disturbances, and observations for which the tilt angle was less than 70°, were all given zero weight. Other observations were taken as having weight unity in forming the normal point.

The next step in the procedure was to obtain by the method of least squares that small circle on the celestial sphere which best fitted the normal points. The coordinates of the normal points were in no case far from the galactic equator which made possible a simplification of the observational equations to a linear form. Letting ℓ_i and b_i be the coordinates of the normal point i, and letting ℓ_0 be a trial value for the galactic longitude of the pole (that is, for ℓ') the observational equations all take the following form:

$$b_i = X - Y\cos(\ell_i - \ell_0) - Z\sin(\ell_i - \ell_0) \qquad (4.11)$$

In these equations the quantities X, Y, Z, are the unknown and they are related to the desired quantities ℓ', b' and θ in the following way:

$$\begin{aligned} X &= 90^\circ - \theta \\ Y &= (90^\circ - b')\cos\Delta \qquad (4.12) \\ Z &= (90^\circ - b')\sin\Delta \end{aligned}$$

In the above the quantity Δ is the correction to the trial value ℓ_o for the longitude of the pole and so is defined by

$$\ell' = \ell_o + \Delta$$

It is to be noted that the quantities X, Y, and Z, are all in degrees. Once the quantities X, Y, and Z have been determined by solving the normal equations, it is a simple matter to derive the desired quantities ℓ', b', and Θ. It is possible to convert ℓ' and b', to right ascension and declination of date and these coordinates can then be precessed to 1900 for comparison with the position of the IAU pole, if desired. The quantity Θ, remains invariable under precession.

It was thought desirable to attempt to obtain an estimate of the accuracy of the three quantities ℓ', b', and Θ. The estimate was arrived at in the following way. First, the weights of the unknowns in the normal equations, X, Y, and Z, were calculated by the ordinary methods of least squares in terms of an observation of unit weight. Next, in order to derive a value for the probable error of an observation of unit weight the root mean square deviation of the normal points from the small circle represented by the values of ℓ', b', and Θ was derived and this was expressed as a probable error of observation of unit weight. From these data it was a simple matter to arrive at the probable errors of the three quantities ℓ', b', and Θ, by ordinary formulas for the propagation of errors. These probable errors can furthermore be transformed into errors of right ascension and declination of the pole, if so desired. It is felt that probable errors obtained in this way are at any rate impersonal and hence, are of some value in assessing the internal consistency of the observations. The final results are for the year 1900.0:

$$l' = 266^\circ.8 \pm 4^\circ.5$$

$$b' = 87^\circ.43 \pm 0^\circ.34$$

or

$$\alpha' = 12^h 39^m.36 \pm 0^m.89$$

$$\delta' = +25^\circ 26' \pm 20'$$

$$\Theta = 91^\circ 17' \pm 11'$$

Appendix 1 summarizes the observations and the computations employed in this determination of the 205 Mc radio pole of the galaxy.

Appendix 2 lists the coordinates of the normal points and their weights.

SECTION 5 - OBSERVATIONAL ERRORS

In order to study the galactic radio structure revealed by Figures 2 and 3, it is necessary to understand some of the sources of error inherent in the observational technique used.

The vertical pattern of the antenna was modified by ground reflections for elevation angles below about 8°. Careful checks on the performance of the antenna at low elevation angles indicated a maximum error of about 2° in elevation pointing which, moreover, was an irregular function of azimuth. Partly for the above reason, data taken at 0° antenna elevation were omitted from the pole solution. The nature of the experimental method minimized the importance of errors in elevation pointing so that even two degrees was a nearly negligible quantity. But, an additional effect prompted the exclusion of the 0° gauges. The local surroundings produced a thermal radiation, variable in azimuth, easily measurable and of nearly the same magnitude as the radiation received from the weaker parts of the galaxy. If a greater range of galactic longitude had been available for observation, it would have been preferable to omit all data to perhaps as high as 12°. It is unfortunate that it was necessary to observe certain of the weaker parts of the galaxy at low elevation angles.

Failure to sweep normal to the galactic distribution of the radio frequency radiations tended to broaden the apparent width of the source. At high elevation angles the effect was aggravated and accompanied by a large shift in the positions of the apparent maxima. For these reasons all data accompanied by a tilt angle less than 70° were omitted from both the pole solution and Figures 2 and 3.

Scatter of points representing nearly the same part of the galaxy arose from four factors. First, there is the time lag and sensitivity of the recorder. This scatter can be clearly seen to divide the measures taken between galactic longitudes minus 30° and plus 10° into two parallel patterns about 1/2° apart. These points were clearly split into two groups because the galactic signal was strongest in this region, making for most accurate positioning, and the angular rate of rotation was highest, because of the low antenna elevation required. This "elevation scatter" is proportional to the cosine of the elevation angle. Tests were performed with a distant transmitter on the ground (zero elevation) and a consistent value of 0.65° spread between maxima for opposite sense of rotation obtained.

Second, there was scatter produced by physical flexing and uncertainty of operation of the driving mechanism, particularly in strong, gusty, winds. This form of error was less than 1°.

Finally, there was scatter resulting from the relative weakness of the galactic signals when compared to the internal receiver noise. The receiver produced 2000 units of noise at the output. Variations in this noise as small as 1 unit in a period of one second could be recognised. The galactic radiations produced maxima over the range 15 to 130 units and the thermal radiations from the ground, plus reflected antenna impedance effects, could produce about 10 units. The consequence of this weakness of the galactic signal is apparent between galactic longitude 100° and galactic longitude 200°.

One further cause of scatter arose as a result of the variation of the received galactic radiation with time. Certain regions, notably one in the constellation Cygnus, produced amplitudes of variation as great as two to one in periods of time less than one minute. This apparent variability of the galactic signal was only occasionally present and chiefly in the region of mean galactic longitude 45°. There is no reason to believe that this effect was very serious relative to the overall measures.

SECTION 6 DISCUSSION

The results of the present investigation leave no doubt that the general source of 205 Mc galactic radiation is intimately connected with the structure of the galaxy.

Table 4 shows the position of galactic poles determined from a variety of astronomical observations and summarized by Van Tulder.[3]

TABLE 4*

DETERMINATIONS OF THE POLE OF THE GALAXY

No.	l'	b'	Type
1	191°	87.1°	cB0-cA6
2	298	88.8	" "
3	14	84.5	cA7-cK
4	6	87.0	" "
5	26	88.1	δ Cephei
6	343	87.8	" "
7	349	88.5	" "
8	193	87.0	B1-B2
9	346	88.1	" "
10	12	88.2	" "
11	269	88.3	B0
12	305	88.7	"
13	181	88.2	B0-B5
14	305	89.5	" "
15	301	88.9	O
16	304	89.0	Wolf-Rayet
17	131	89.0	Open clusters
18	0	89.4	" "
19	357	88.5	" "
20	161	84.2	Plan. nebulae
21	41	85.2	" "

No.	l'	b'	Type
22	253°	86.2°	Extra gal. neb.
23	290	88.0	High velocities
24	281	89.4	Stars far from gal. plane

* Adapted from reference 3

Table 5 shows the positions of the galactic pole as computed by Northcott and Williamson[2] from Reber's observations of galactic noise at 160 Mc and 480 Mc. For purposes of comparison, the results of the present determination are also included.

TABLE 5

THE GALACTIC POLE FROM GALACTIC NOISE AT THREE FREQUENCIES

Freq.	Observer	R. A. (1900)	Dec. (1900)	θ
160	Reber	$12^h34^m.5 \pm 1^m.1$	$+27°.10 \pm 0.26$	$91°.61 \pm 0°.20$
205	Cornell	$12\ 39.4 \pm 0.9$	$+25.43 \pm 0.34$	91.28 ± 0.19
480	Reber	$12\ 40.9 \pm 2.7$	$+29.10 \pm 0.87$	90.72 ± 0.54

Freq.	Range in Gal. Long.	Normal Points
160	325-210	12
205	326-196	16
480	330-55; 150-180	10

It will be seen that there is nothing in particular to distinguish the positions of the poles of galactic noise from the other poles. Note, for example, the agreement with the determination (number 22) from the zone of avoidance of extra-galactic nebulae. However, the radio determinations have both a higher internal consistency and a considerably smaller probable error. It is tempting to speculate on the possibility of a systematic variation of the position of galactic radiation with frequency, but this must be postponed, partially because of the preliminary nature of the 160 and 480 Mc data.

It is safe to say that the source of the 205 Mc radiation has no connection with the phenomenon of Gould's Belt.[4] The pole of Gould's Belt is approximately 15° away from the north galactic pole, whereas the pole of the 205 Mc radiation is only $2\frac{1}{2}°$ distant and in a different direction.

One provocative result of the radio observations is the fact that the mean galactic latitude of the radiation at 205 Mc differs significantly from zero degrees. If any reliance is to be placed in the determination of the probable errors, it must be conceded that the mean galactic latitude based on the pole of symmetry of the observations is one degree or more south. Reference to table 5 shows that a similar effect was also apparent in the reductions of Reber's data at both 160 Mc and 480 Mc. While it is well known from various astronomical observations that the sun occupies a position somewhat to the north of the galactic plane, it was hardly to be anticipated that so large a value of the mean galactic latitude of the radio noise would be found.

If we accept Van Tulder's value of 13 parsecs for the height of the sun above the galactic plane, we can compute a mean distance for the effective sources of the galactic radio frequency radiation in question. The value comes out to be approximately 750 parsecs.

According to the theory of radiation from a thin slab in thermodynamic equilibrium, this quantity should be directly comparable with the distance at an optical depth of approximately unity in the interstellar medium for the frequency involved. If we make use of the customary values of the electron density and electron temperature in the interstellar medium, however, it is not difficult to compute that on the theory of free-free transitions such a distance must be at least 10 times as great as the one just derived.

There is an alternative way of considering this phenomenon. Assuming that the galactic radiation is to be identified with radiation from the electron gas in interstellar space, we can take 10,000 parsecs as a fair value for the distance corresponding to an optical depth unity. This is quite definitely a minimum value and it is difficult to see how it could be made very much smaller[5]. But, if this is the average distance to the source of radiation, we are forced to the conclusion that the sun must be at least several hundred parsecs above the central plane of the radiating medium in order to give the observed value of minus 1° for the mean galactic latitude of the signal.

In this way one is led to see the crucial nature of the conclusion that the centroid of the galactic radiation departs noticeably from a great circle on the celestial sphere. If we agree with this conclusion, we must either adopt the optical depth of the galaxy computed for the radiation at 205 Mc or alternatively, change our ideas about the height of the sun above the median plane of the galaxy. It becomes of considerable importance then to test in any way possible the reliability of the value of Q which has been derived. In this regard, particular attention should be paid to the unavoidable gap in the observations between galactic longitude 200° and 320°. This gap is, of course, caused by the northern latitude of the observing station, which makes a portion of the celestial sphere invisible from the observing station at any time of the year. In principle, at least, the comparatively high weight of the solution for the unknown X in equation (4,11) indicates that no difficulty is to be expected about the determination of this quantity because of the gap in galactic longitude. At the same time, it was felt worthwhile to make an additional computational test of the reality of the value obtained for X.

The relevant question in this connection is the following. How well can the present data be represented by a solution in which it is assumed that there is no deviation of the centroid of the galactic signal from a great circle? In order to answer this question the sixteen observational equations representing the sixteen normal points were altered by setting X identically equal to zero, then forming the normal equations which were solved for ℓ' and b'. From these normal equations, weights for ℓ' and b' were formed. By comparing the deviation of the computed values of b from the observed value for the longitude of each normal point, a probable error for an observation of unit weight was obtained. Combining these results, it was possible to obtain new probable errors for the quantities ℓ' and b' corresponding to the assumption that the centroid of the galactic radiation does not differ from a great circle. The probable errors from this computation are exhibited in Table 6 along with the probable errors from the more general solution for purposes of comparison.

TABLE 6

COMPARISON OF PROBABLE ERRORS OF ℓ' AND b' FOR TWO ALTERNATIVE HYPOTHESES ABOUT X

	$X \neq 0$	$X \equiv 0$
ℓ'	$\pm 4\overset{\circ}{.}5$	$\pm 15\overset{\circ}{.}7$
b'	$\pm 0\overset{\circ}{.}3$	$\pm 0\overset{\circ}{.}8$

Since the method of determining the probable errors takes into account the fact that there are three adjustable parameters in one of the solutions and only two in the other, this cannot be a source of the difference of the probable errors in the two cases. It is seen then that the probable errors for the position of the pole are more than doubled by requiring the observations to fit a great circle rather than the optimum small circle. The conclusion to be drawn from this is presumably that the observations are definitely better fitted by a small circle corresponding to X equal to approximately minus one degree than they are by the corresponding great circle. However, in view of the considerable astrophysical interest in the exact value of Θ, a final decision must await observations made in latitudes such that the gap in observable galactic longitude is greatly lessened or completely done away with. Also, it would be desirable to take into account the effects of any discrete sources that may be isolated.

Reference to Figure 3 raises the distinct possibility that the distribution of the normal points about the computed curve is by no means random in nature. We believe that the indications are quite definite that a fair proportion of the deviation of the normal points from the curve represents real observational data. While it is barely possible that these deviations are the results of local peculiarities of the terrain near the radio telescope employed, this seems hardly likely for several reasons. In the first place, no similar effects have been noted during other observations; for example, observations of the sun and observations of the horizon when no important sources of cosmic noise are in the sky. There is also the fact that effects due to local terrain would be intimately correlated with altitude and because of the design of the observing program many of the regions were observed twice at quite different altitudes. In spite of this fact the systematic nature of the deviations remains. A means of testing the reality of these deviations from the computed curve is available. The probable error of an observation of unit weight can be obtained in the process of determining probable errors for the three desired quantities ℓ' and b' and θ by making use of the root mean square deviation of the normal points from the computed curve. It is also possible to calculate a probable error for an observation of unit weight by finding the root mean square deviation of the individual observations from the position of their normal point. If the two probable errors computed in this way are substantially identical, the conclusion is that there is no significant deviation of the normal point from the computed curve. On the other hand, if it is found that the probable error for a given normal point computed with respect to the dispersion of the individual observations about the normal point, is a great deal smaller than the deviation of that normal point from the curve, there is evidence of a significant deviation of the observations from the computed curve in that region.. Table 7 exhibits the findings of such calculations.

TABLE 7

INTERNAL CONSISTENCY OF THE OBSERVATIONS

Normal Pt. No.	Deviation of normal point from computed curve	Probable error of Normal point from internal consistency
1 *	+ 0°601	0°06
2	+ .228	.07
3	+ .354	.06
4	− .068	.06
5 *	− 2.350	.06
6	− 0.364	.21
7	+ .941	.11
8	− .317	.09
9	− .941	.16
10	+ .663	.08
11 *	+ 1.124	.10
12	+ 0.617	.14

Normal Pt. No.	Deviation of normal point from computed curve	Probable error of Normal point from internal consistency
13*	- 1.171	0°.10
14	- 0.320	.09
15	- .005	.09
16	- .112	.20

P.E. of a normal point from agreement with a computed curve ± 0°.89

*Points whose deviation from the curve is > 10 times the P. E.

Significant deviations from the smooth computed curve are evident. Moreover, several of the deviations seem to be adequately accounted for by the positions of known radio "point" sources near the galactic plane. For example, Cygnus A at galactic longitude 45° has a galactic latitude of + 5° and it will be noted that the systematic deviation of the centroids in this region is in the direction of positive galactic latitude. Similarly Cassiopeia A at galactic longitude 79° and galactic latitude 2° seems to exert an influence on the position of the centroid in this region of the celestial sphere. Taurus A at galactic longitude 154° and galactic latitude -4° seems to be a logical cause for the deviation of the centroid in that region.*

*At the time these observations were first reduced, Bolton, Stanley, and Slee, (NATURE, Vol. 164, Pg. 101, 1949) had not yet announced the correction to their original position for Taurus A which increased the galactic longitude of this point by 9° while leaving its galactic latitude unchanged. On the basis of the incorrect position, it would have been difficult to interpret the systematic deviation of the centroids from the plane of the galaxy in the one region and the lack of such systematic deviations in the other regions. This seems to suggest that a radio telescope with a conventional type of antenna may have some advantages for determining directions of isolated sources of radio frequency energy which are not possessed by present interferometer techniques.

The data represented in Figure 2 has been included because of its general interest although it is of considerably lower accuracy than the data relative to the centroids of the galactic signals as a function of galactic longitude. It should be borne in mind that it must be regarded as of a provisional nature. The relative intensity curve shows quite clearly the marked increase in specific intensity of galactic radiation toward the galactic center. Coordinates of this curve correspond to the maximum signal obtained for any sweep and are plotted as functions of galactic longitude. The zero of this curve corresponds approximately to the meter deflection obtained when the radio telescope is pointed near one of the galactic poles at a time when the sun is not in the sky. The secondary maxima of this curve occur at galactic longitudes which are approximately coincident with the positions of the three radio stars, Cygnus A, Cassiopeia A, and Taurus A. Apart from these three points the variation seems to be of quite a smooth nature.

It is possible to arrive at an order of magnitude estimate of the specific intensity of the galactic radiation in terms of the specific intensity of the solar radiation in the following way. When the radio telescope is directed at the quiet sun at a season when galactic radiation is not entering the radio telescope in appreciable quantity, the relative intensity is approximately 140 milovolts. When the radio telescope is directed toward the sun, the flux at the antenna comes from a solid angle determined by the angular diameter of the radiating portion of the sun at this frequency, which may be taken to be approximately 1°. However, when the radio telescope is directed at a portion of the galaxy the flux at the antenna is partly determined by the half width of the antenna pattern which is approximately 15° for the radio telescope used here. Making use of these facts, the following simple expression can be derived for the specific intensity of the galactic radiation in any galactic longitude as compared with the specific intensity of solar radiation for the frequency concerned.

$$\frac{(I_\nu)_{gal}}{(I_\nu)_{sun}} = \frac{I_{rel}}{140}\left(\frac{1}{15}\right)^2 \doteq 0.3\, I_{rel} 10^{-4} \qquad (6.1)$$

It cannot be too strongly emphasized that the above equation is not a result of absolute calibrations and is included merely as an order of magnitude estimate in order to give additional meaning to the data represented in Figure 2.

At the same time that one of the complete checks of the data read from the tape for the solution of the radio pole was being made, data were taken from the tapes for the purpose of calculating approximate half widths for the radiating region of the galaxy in the various galactic longitudes. To do this, a minimum was established by drawing a straight line between the minima on either side of the galactic plane. A line parallel to this was then drawn which was half way from minimum to maximum value of the signal. The difference in azimuth of these two "half signal" points was then read from the azimuth calibration marks. From this a rough value of the width in galactic latitude of the observed distribution was then computed for each sweep by the following equation:

$$\Delta b = \Delta Z \cos \psi \cos h \qquad (6.2)$$

In the above equation Δb is the half width in galactic latitude of the observed intensity distribution, ΔZ is the earth observed half width in azimuth as read from the tape, ψ is the tilt angle as defined in Section 4 and h is the altitude of the sweep. No attempt has been made in the data represented by Figure 2 to correct for the finite width of the antenna pattern in order to obtain an approximate half width for the actual intensity distribution of the galactic radiation. Such refinements must await further observations. An interesting feature of Figure 2 is that it exhibits no general trend for a widening of the radiating region toward the direction of the galactic center. As a matter of fact, the apparent trend is in the opposite direction so that wide, but faint radiating regions of the galaxy are indicated for galactic longitudes nearer the anti-center rather than the center. A rough estimate of the actual half width of the galactic radiation can be obtained by application of the following equation.

$$(\bar{H})_p^2 = (\bar{H})_s^2 + (\bar{H})_A^2 \qquad (6.3)$$

In this equation $(\bar{H})_A$ represents the half width of the antenna pattern, Θ_s represents the half width of the true source distribution, and Θ_p represents the half width of the observed distribution. This equation would be exact if all the distributions mentioned were of the normal or gaussian type. Since the distributions are only approximately of this type, the equation must be regarded as a purely approximate one. The quantity Θ_p may be read from Figure 2 and the quantity Θ_A may be taken to be 15°. It appears that the true half width of the radiating regions of the galaxy may vary from between 10° and 25° and that a reasonably accurate value at zero degrees galactic longitude would be approximately 15° from the half intensity point on one side of the galactic plane to the half intensity point on the other side of the galactic plane for 205 Mc radiation.

SECTION 7 - Acknowledgments

Many other members of this project besides the authors participated in this measurement of the position of the radio galactic pole. W. E. Gordon and B. M. Fannin contributed much to the organization and execution of the observations. Mrs. John Tryon performed nearly all the tape measurements and subsequent computations.

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APPENDIX I

Summary of Data

The coordinates of the centroid of the received signal for each observation are tabulated. The symbols are defined as follows:

N_p Normal point number

ℓ Galactic longitude

b Galactic latitude

wt Weight of point. Zero weights were assigned for reasons indicated in the table by:

a - zero elevation angle

b - $|\Upsilon| > 70^\circ$

c - record badly asymmetric

run Date (number) and relative time of day (a-early evening, b-late)

$\frac{db}{dt}$ Direction of sweep, + indicates direction of increasing galactic latitude

alt Altitude of telescope

az Azimuth of telescope

GCT Greenwich Civil Time

Υ Tilt angle between direction of sweep and galactic equator

1/2wd Width in degree galactic latitude between half amplitude points.

I_{rel} Relative intensity of maximum signal

Lp	ℓ	b	wt.	run	$\frac{db}{dt}$	alt	az.	GCT	⊣	1/2wd	I_{rel}
1	322°.048	−0°.890	0a	5a	+	2°.0	218°.7	$23^h48^m37^s$	89°.6	19°	100 mv.
	323.702	−1.790	0a	4a	−	2.0	220.3	00 06 40	87.7	21	105
	323.935	−0.900	0a	2a	+	2.0	221.5	00 16 15	87.4	21	110
	324.883	−1.207	0a	1a	−	2.0	222.6	00 27 58	86.4	20	135
	326.548	−1.722	2	5a	−	5.5	219.5	23 57 20	88.6	19	120
	327.467	−0.347	0a	3a	+	2.0	226.6	00 39 45	83.8	21	100
	328.210	−1.807	2	2a	−	5.5	222.0	00 22 54	86.7	20	120
	328.260	−1.132	2	4a	+	5.5	222.7	00 15 10	86.6	21	120
	329.447	−0.880	1	1a	+	5.5	224.7	00 36 05	85.4	21	140
	331.538	−1.337	2	5a	+	9.1	222.2	00 08 40	87.0	22	125
	331.617	−1.768	2	3a	−	5.5	227.1	00 45 08	83.3	22	112
	332.577	−2.045	2	4a	−	9.1	223.2	00 21 15	86.0	20	125
	332.958	−1.142	2	2a	+	9.1	224.6	00 31 31	85.5	20	125
	333.623	−2.070	2	1a	−	9.1	224.8	00 41 07	84.9	22	150
	336.297	−1.903	2	5a	−	12.8	223.6	00 17 15	86.0	22	120

Np	ℓ	b	wt.	run	$\frac{db}{dt}$	alt	az.	GCT	$\frown\!|\!\frown$	1/2wd	I_{rel}
2	336°.568	−1°.145	2	3a	+	9°.1	230°.0	$00^h54^m00^s$	82°.2	21°	110 mv.
	337.275	−2.222	2	2a	−	12.8	224.9	00 36 49	85.0	20	120
	337.453	−1.185	2	4a	+	12.8	226.1	00 29 35	84.7	22	120
	338.482	−1.432	2	1a	+	12.8	227.5	00 49 11	83.8	21	130
	340.970	−1.778	2	3a	−	12.8	231.0	00 59 14	31.6	23	110
	341.693	−1.137	2	5a	+	16.6	227.2	00 28 45	34.3	23	115
	341.883	−1.822	2	4a	−	16.6	226.9	00 34 35	84.2	22	120
	342.452	−1.965	2	2a	+	16.6	227.7	00 46 44	83.7	21	115
	342.952	−1.732	2	1a	−	16.6	228.7	00 54 04	83.2	24	130
	346.272	−0.780	2	3a	+	16.6	234.6	01 07 54	80.3	22	110
3	346.770	−1.285	2	5a	−	20.5	229.4	00 37 10	83.2	24	110
	347.193	−1.395	2	2a	−	20.5	230.0	00 52 03	82.8	22	115
	347.280	−0.517	2	4a	+	20.5	230.9	00 44 00	82.5	22	110
	348.143	−0.841	2	1a	+	20.5	232.0	01 02 01	81.8	23	120
	351.165	−1.325	2	3a	−	20.5	236.3	01 14 34	79.5	23	105

Gp	l	b	wt.	run	$\frac{db}{dt}$	alt	az.	GCT	ψ	1/2wd	I_{rel}
3	352°.432	-1°.228	2	4a	-	24°.5	232°.7	$00^h52^m15^s$	81°.6	22°	110 mv.
	352.615	-0.530	2	5a	+	24.5	233.6	00 48 50	81.2	25	110
	352.808	-1.363	2	1a	-	24.5	233.2	01 06 43	81.3	24	120
	352.907	-0.503	2	2a	+	24.5	234.1	01 02 33	80.9	23	105
	356.828	-0.545	2	3a	+	24.5	240.2	01 23 29	77.9	23	105
4	357.763	-1.495	2	5a	-	28.5	235.3	00 57 05	80.3	24	100
	358.038	-1.437	2	2a	-	28.5	235.8	01 10 33	80.1	22	100
	358.218	-0.738	2	1a	+	28.5	236.7	01 14 52	79.6	24	110
	358.358	-0.773	2	4a	+	28.5	236.9	01 04 00	79.6	23	100
	1.462	-1.782	2	3a	-	28.5	241.0	01 28 23	77.6	22	95
	3.288	-1.573	2	1a	-	32.5	238.5	01 22 08	78.8	25	100
	3.498	-1.973	2	4a	-	32.5	283.5	01 12 08	78.9	23	90
	3.502	-1.295	2	2a	+	32.5	239.1	01 19 11	78.5	21	90
	3.795	-1.157	2	5a	+	32.5	239.7	01 09 00	78.2	22	90
5	7.140	-1.560	2	3a	+	32.5	244.7	01 37 23	76.0	24	85

Kp	ℓ	b	wt.	run	$\frac{db}{dt}$	alt	az.	GCT	[illegible]	1/2wd	I_{rel}
5	8°.835	−2°.305	2	2a	−	36°.5	241°.3	$01^h28^m03^s$	77°.6	18°	85 mv.
	8.993	−2.155	2	5a	−	36.5	241.7	01 17 00	77.4	24	76
	9.335	−1.675	2	1a	+	36.5	242.7	01 34 08	76.9	23	85
	9.623	−1.763	2	4a	+	36.5	243.1	01 24 10	76.7	23	80
	14.762	−2.365	2	1a	−	40.5	245.5	01 42 45	75.7	25	70
	14.907	−2.085	2	2a	+	40.5	246.0	01 39 14	75.4	24	65
	14.915	−2.533	2	4a	−	40.5	245.6	01 32 05	75.7	23	64
	15.162	−2.220	2	5a	+	40.5	246.3	01 29 05	75.3	24	64
	15.540	−2.733	2	3a	−	36.5	251.6	02 03 03	73.4	24	65
	18.613	+0.480	0a	1b	−	2.0	290.9	05 31 27	72.9	34	40
	19.437	+0.618	0a	2b	−	2.0	292.0	05 31 44	73.2	32	37
6	19.958	+0.290	0a	3b	−	2.0	292.4	05 31 20	73.4	31	38
	20.012	+2.560	0a	5b	+	2.0	294	05 19 55	73.1	29	7
	20.028	−1.382	1	5a	−	44.5	219.8	01 31 45	73.3	24	52
	20.407	−2.453	2	2a	−	44.5	219.4	01 47 24	73.8	25	51

Np	ℓ	b	wt.	run	$\frac{db}{dt}$	alt	az.	GCT	ψ	1/2wd	I_{rel}
6	21°193	−1°638	1	1a	+	44°5	251°5	$01^h54^m18^s$	72°5	26	48 mv.
	21.337	−2.203	2	4a	+	44.5	251.2	01 44 15	73.0	24	50
	21.682	−2.105	1	3a	+	40.5	256.7	02 12 21	71.1	26	50
	22.598	+1.813	0a	4b	+	2.0	296.7	05 40 00	74.3	32	34
	24.043	+0.177	1	5b	−	5.5	293.9	05 26 10	73.6	33	38
	24.437	−0.353	1	1b	+	5.5	294.0	05 44 59	73.8	29	37
	25.638	+0.870	1	3b	+	5.5	296.3	05 41 58	74.0	30	40
	25.975	+0.997	1	2b	+	5.5	296.8	05 47 40	74.2	30	37
	26.432	+0.778	1	4b	−	5.5	297.2	05 42 50	74.6	32	36
	26.875	−1.515	1	1a	−	48.5	256.0	02 01 53	70.2	30	40
	27.015	−1.763	0b	3a	−	44.5	260.6	02 17 18	69.1	28	44
	27.148	−1.568	1	2a	+	48.5	256.4	01 59 28	70.0	26	39
	27.293	−1.307	0b	4a	−	48.5	256.9	01 51 52	69.7	26	40
	28.558	−0.463	0b	5a	+	48.5	259.8	01 52 45	68.0	26	40
	29.388	−0.318	1	1b	−	9.1	296.5	05 51 51	74.2	26	37

Hp	ℓ	b	wt.	run	$\frac{db}{dt}$	alt	az.	GCT		1/2wd	I_{rel}
6	29°723	+0°245	1	3b	−	9°1	297.3	$05^h45^m00^s$	74°2	28°	40 mv.
	30.237	+0.652	1	2b	−	9.1	298.2	05 51 16	74.3	31	37
	30.348	+0.740	1	5b	+	9.1	298.4	05 40 00	74.3	27	38
	32.063	+1.228	1	4b	+	9.1	300.8	05 53 25	75.0	27	35
7	34.140	+1.070	0b	2a	−	52.5	266.1	02 07 05	63.4	24	41
	35.015	+2.297	0b	5a	−	52.5	268.8	01 56 33	61.4	23	40
	35.337	+2.463	0b	3a	+	48.5.	273	02 27 00	61.2	26	44
	35.540	+2.298	0b	1a	+	52.5	269.6	02 14 38	61.1	26	40
	35.653	+2.402	1	5b	−	12.8	302.4	05 46 00	74.2	31	40
	36.030	+1.793	1	1b	+	12.8	302.4	06 05 07	74.6	25	43
	36.132	+1.633	1	3b	+	12.8	302.4	05 58 08	74.7	27	46
	36.250	+0.907	1	4b	−	12.8	302.0	05 56 10	75.1	28	40
	36.375	+3.083	0b	4a	+	52.5	271.7	02 04 38	59.6	26	42
	36.788	+1.798	1	2b	+	12.8	303.3	06 05 54	75.0	26	43
	40.535	+1.617	1	3b	−	16.6	304.0	06 01 03	74.6	23	50

Hp	ℓ	b	wt.	run	$\frac{db}{dt}$	alt	az.	GCT	⊥	1/2wd	I_{rel}
7	40°793	−1°310	0c	2b	−	16°6	302°	$06^h11^m21^s$	76°1	25°	47 mv.
	41.007	+1.955	1	1b	−	16.6	304.8	06 11 18	74.7	20	50
	41.745	+2.348	0b	1a	−	56.5	276.3	02 21 33	56.4	19	45
	41.798	+2.327	1	5b	+	16.6	306	06 00 00	75.0	—	64
	42.180	+2.020	1	4b	+	16.6	306.2	06 06 56	75.4	24	48
	42.182	+4.525	0b	3a	−	52.5	282	02 30 45	54.3	19	56
	42.365	+2.528	0b	2a	+	56.5	277.5	02 19 51	55.7	20	51
	42.415	+2.733	0b	4a	−	56.5	277.8	02 11 34	55.4	20	48
	43.082	+3.032	0b	5a	+	56.5	279.2	02 09 40	54.5	19	48
	46.020	−3.548	0b	2a	−	60.5	273	02 32 19	61.4	21	35
	46.577	+1.043	1	4b	−	20.5	306.9	06 11 00	75.7	20	54
	46.922	+2.178	1	3b	+	20.5	308.2	06 15 13	75.3	20	54
	46.967	+3.105	1	5b	−	20.5	309	06 06 00	74.8	—	56
	47.027	+1.418	1	1b	+	20.5	307.7	06 25 07	75.8	20	54
	47.270	+1.537	0b	3a	+	56.5	284.1	02 41 08	54.0	17	54

Ep	ℓ	b	wt.	run	$\frac{db}{dt}$	alt	az.	GCT		1/2wd	I_{rel}
7	47°.600	+1°.140	1	2b	+	20°.5	308°.1	$06^h25^m27^s$	76°.4	24°	53 mv.
	47.622	+0.413	0b	5a	–	60.5	281.0	02 16 20	53.9	—	50
	48.588	+0.872	0b	1a	+	60.5	283.2	02 34 50	52.4	15	44
	48.818	+0.692	0b	4a	+	60.5	283.4	02 24 17	52.5	—	50
	51.512	+0.510	1	3b	–	24.5	308.4	06 21 08	76.1	22	50
	51.523	–0.453	0b	3a	–	60.5	286.2	02 44 30	52.8	—	50
	51.868	+0.655	1	1b	–	24.5	308.9	06 31 11	76.3	21	44
	52.140	–1.590	0b	2a	+	64.5	279	02 42 07	58.1	16	55
	52.388	+0.382	1	2b	–	24.5	309.2	06 31 12	76.9	26	45
	52.802	+1.705	1	5b	+	24.5	310.8	06 20 05	76.3	25	42
	52.970	+1.615	1	4b	+	24.5	310.9	06 25 22	76.5	24	45
8	53.345	–1.495	0b	1a	–	64.5	286.1	02 41 32	51.0	12	32
	53.555	–1.722	0b	4a	–	64.5	286.1	02 31 28	51.3	—	40
	54.345	–1.382	0b	5a	+	64.5	288	02 29 45	50.0	—	36
	57.390	+0.235	1	5b	–	28.5	311	06 25 50	77.2	25	36

lp	ℓ	b	wt.	run	$\frac{db}{dt}$	alt	az.	GCT	ψ	1/2wd	I_{rel}
8	57°.438	−0°.342	1	4b	−	28.5	310°.5	$06^h31^m00^s$	77°.7	25°	35 mv.
	57.707	+0.648	1	3b	+	28.5	311.7	06 35 15	77.2	21	40
	57.992	+0.562	1	1b	+	28.5	311.9	06 45 18	77.5	26	36
	58.242	−1.482	0b	3a	+	64.5	294.3	02 55 00	47.6	—	38
	58.688	+1.008	1	2b	+	28.5	313.0	06 45 38	77.8	26	35
	62.610	+0.642	1	3b	−	32.5	313.5	06 41 00	77.3	22	34
	62.838	+0.437	1	1b	−	32.5	313.5	06 50 54	77.7	25	30
	63.752	+1.502	1	5b	+	32.5	315.4	06 40 10	77.7	27	28
	63.838	+1.127	1	4b	+	32.5	315.1	06 45 25	78.1	31	30
	64.810	+0.887	1	2b	−	32.5	315.7	07 00 56	79.3	29	31
	68.438	+0.890	1	5b	−	36.5	316.3	06 45 45	78.2	25	30
	68.643	+1.112	1	4b	−	36.5	316.7	06 50 52	78.2	28	32
	68.767	+1.383	1	3b	+	36.5	317.1	06 55 18	78.1	23	34
	68.933	+0.815	1	1b	+	36.5	316.6	07 05 22	78.8	26	34
	71.735	+0.222	1	2b	+	36.5	313	07 24 15	82.8	25	33

Np	ℓ	b	wt.	run	$\frac{db}{dt}$	alt	az.	GCT	ψ	1/2wd	I_{rel}
8	73°.103	+0°.562	1	3b	–	40°.5	317°.6	$07^h00^m57^s$	78°.9	22°	40 mv.
	73.530	–0.168	1	1b	–	40.5	316.8	07 10 52	79.8	24	36
	74.282	+0.418	1	5b	+	40.5	318	07 00 15	80.2	—	48
	74.113	+0.497	1	4b	+	40.5	318.2	07 05 22	80.3	24	37
	75.877	–1.078	1	2b	–	40.5	317.1	07 26 23	83.8	23	39
9	78.987	+0.195	1	5b	–	44.5	319.0	07 05 45	80.6	17	45
	79.020	–0.487	1	4b	–	44.5	318.1	07 10 50	81.5	23	41
	79.267	+0.392	1	3b	+	44.5	319.4	07 15 38	80.8	23	40
	79.383	–0.317	1	1b	+	44.5	318.5	07 25 22	81.8	21	42
	81.365	–1.298	1	2b	+	44.5	318	07 38 17	85.9	19	45
	83.848	–0.313	1	3b	–	48.5	319.5	07 20 56	81.9	26	40
	84.045	–0.690	1	1b	–	48.5	319.0	07 30 51	82.7	21	39
	84.818	+0.515	1	5b	+	48.5	321	07 20 15	82.4	24	40
	84.860	–0.435	1	4b	+	48.5	319.6	07 25 31	83.7	26	38
	85.695	+5.510	0b	5a	–	64.5	09	02 25 10	27.4	—	32

Np	l	b	wt.	run	$\frac{db}{dt}$	alt	az.	GCT	Υ	1/2wd	I_{rel}
9	87°.507	+4°.812	0b	4a	+	64°.5	12°	$02^h 36^m 00^s$	28°.7	—	34 mv.
	89.223	−0.918	1	2b	+	48.5	319.5	08 09 55	88.1	22	35
	89.417	−0.040	1	5b	−	52.5	321	07 25 40	82.6	24	30
	89.420	+4.130	0b	3a	−	64.5	15	02 50 20	29.2	—	36
	89.562	−0.040	1	4b	−	52.5	321.0	07 30 52	83.8	22	34
	89.683	+0.320	1	3b	+	52.5	321.6	07 35 29	83.5	26	34
	89.938	+0.440	1	1b	+	52.5	321.8	07 45 28	83.8	24	35
	92.107	+5.782	0b	5a	+	60.5	21	02 20 35	39.8	—	26
	93.420	+1.185	1	2b	−	52.5	322.7	08 11 52	89.8	29	29
	93.888	+3.500	0b	1a	−	60.5	22.5	02 30 33	47.0	19	26
	94.555	+1.983	1	3b	−	56.5	325.3	07 41 05	81.6	28	30
	94.690	+1.468	1	1b	−	56.5	324.3	07 50 52	82.9	23	30
	94.893	+2.637	0b	4a	−	60.5	30	02 20 37	48.7	—	32
	95.323	+2.008	1	5b	+	56.5	325.1	07 40 23	83.2	28	28
	95.473	+2.2[illegible]	1	4b	+	56.5	325.4	07 45 35	83.4	26	37

Np	ℓ	b	wt.	run	$\frac{db}{dt}$	alt	az.	GCT		1/2wd	I_{rel}
9	95°998	−3°645	0b	2a	−	64°5	41°1	$02^h38^m13^s$	56°4	17°	25 mv.
	96.010	+5.727	0b	2a	−	56.5	28.1	02 15 45	50.1	19	29
	97.440	+3.213	0b	3a	+	60.5	30	02 48 40	43.4	—	30
10	98.658	+3.563	0b	4a	+	56.5	33.6	02 15 32	53.2	20	30
	98.662	+2.018	1	2b	+	56.5	323.6	08 23 09	88.5	28	27
	98.788	+2.280	0b	5a	−	56.5	36	02 05 35	56.5	23	26
	99.773	−2.632	0b	2a	+	60.5	43.8	02 36 03	59.1	19	25
	99.938	+2.327	1	5b	−	60.5	326.3	07 45 37	88.1	27	26
	100.150	+2.307	1	3b	+	60.5	326.1	07 55 34	84.0	27	30
	100.213	+1.903	1	4b	−	60.5	325.2	07 52 35	85.0	25	37
	100.373	+2.388	1	1b	+	60.5	326.1	08 05 30	84.4	25	30
	100.807	+3.790	0b	3a	−	56.5	34.6	02 37 02	50.2	—	30
	101.778	+2.800	0b	1a	−	52.5	38.3	02 10 48	60.9	23	25
	101.817	+3.147	0b	4a	−	52.5	37.8	02 00 48	60.1	26	28
	101.878	+3.305	0b	2a	+	52.5	37.6	02 09 51	59.6	30	31

Hp	ℓ	b	wt.	run	$\frac{db}{dt}$	alt	az.	GCT	-+-	1/2wd	I_{rel}
10	102°.242	+3°.202	0b	5a	+	52°.5	38°.0	$02^h00^m20^s$	59°.5	23°	24 mv.
	102.997	+1.815	1	2b	–	60.5	322.7	08 26 03	87.2	32	28
	104.655	+1.488	1	3b	–	64.5	324.5	08 00 50	86.4	25	30
	104.870	+1.307	1	1b	–	64.5	323.8	08 10 48	87.5	27	30
	105.047	+2.767	0b	5a	–	48.5	40.7	01 45 45	64.9	27	26
	105.125	+2.147	0b	2a	–	48.5	41.6	01 55 56	66.0	30	27
	105.448	+3.533	0b	4a	+	48.5	40.0	01 55 25	63.2	26	28
	105.468	+1.787	1	5b	+	64.5	324.2	08 00 22	87.8	26	26
	105.610	+1.905	1	4b	+	64.5	324.3	08 05 37	88.5	25	37
	105.638	+2.653	0b	1a	+	48.5	41.3	02 05 24	64.6	25	25
	107.650	+0.390	0b	3a	+	52.5	46.2	02 34 35	60.4	17	32
	108.112	+2.478	0b	1a	–	44.5	42.6	01 50 51	68.8	28	23
	108.283	+2.210	1	2b	+	64.5	321.4	08 37 29	83.8	26	28
	108.328	+2.537	0b	4a	–	44.5	42.7	01 40 50	68.5	26	26
	108.578	+2.615	0b	2a	+	44.5	42.8	01 50 47	68.1	31	25

Hp	ℓ	b	wt.	run	$\frac{db}{dt}$	alt	az.	GCT	ψ	1/2wd	I_{rel}
10	108°.883	+2°.315	0b	5a	+	44°.5	43°.4	$01^h40^m20^s$	68°.2	30°	26 mv.
	109.265	+2.653	0b	3a	–	48.5	44.2	02 23 14	61.3	29	30
	111.110	+1.808	1	2a	–	40.5	44.3	01 35 56	72.4	30	27
	111.457	+1.438	1	5a	–	40.5	45.0	01 25 50	72.5	25	24
	111.873	+2.473	1	4a	+	40.5	44.2	01 35 20	70.8	32	26
	111.920	+1.870	1	1a	+	40.5	44.9	01 45 58	71.5	29	25
	113.570	+2.320	0b	3a	+	44.5	47.4	02 20 48	64.4	31	26
	113.823	+2.650	1	1a	–	36.5	43.7	01 30 51	74.0	26	25
	114.383	+2.737	1	2a	+	36.5	44.1	01 31 17	73.4	32	27
	114.597	+0.812	1	4a	–	36.5	46.3	01 21 00	75.2	30	26
	114.752	+1.797	1	5a	+	36.5	45.4	01 20 10	74.0	30	22
11	116.440	+1.678	0b	3a	–	40.5	49.1	02 08 58	68.0	25	28
	116.810	+1.408	1	2a	–	32.5	45.2	01 15 59	77.2	29	25
	117.062	+1.238	1	5a	–	32.5	45.6	01 05 45	77.1	30	25
	117.452	+1.793	1	1a	+	32.5	45.4	01 25 20	76.2	28	25

Np	ℓ	b	wt.	run	$\frac{db}{dt}$	alt.	az.	GCT	-|-	1/2wd	I_{rel}
11	117°.625	+2°.055	1	4a	+	32°.5	45°.3	$01^h15^m18^s$	75°.8	35°	25 mv.
	119.705	+1.890	1	1a	–	28.5	44.6	01 11 42	78.6	29	30
	119.853	+2.965	0b	3a	+	36.5	49.0	02 06 25	68.6	30	25
	119.865	+1.448	1	3a	–	32.5	48	01 34 10	74.4	26	25
	119.902	+1.570	1	4a	–	28.5	45.1	01 00 55	78.6	34	25
	120.347	+1.495	1	5a	+	28.5	45.6	01 00 10	78.3	30	25
	120.392	+2.380	1	2a	+	28.5	44.8	01 13 43	77.6	26	25
	122.492	+1.530	1	5a	–	24.5	44.5	00 45 45	80.6	36	25
	122.592	+2.377	1	2a	–	24.5	43.8	00 59 26	80.0	25	25
	123.013	+2.743	1	4a	+	24.5	43.9	00 55 20	79.3	37	22
	123.288	+3.053	1	1a	+	24.5	43.9	01 09 42	78.8	24	28
	123.435	+2.200	1	3a	+	28.5	48	01 31 32	75.0	28	25
	125.522	+0.570	1	4a	–	20.5	45	00 40 55	82.5	36	25
	125.817	+1.550	1	5a	+	20.5	44.4	00 40 15	81.7	33	25
	125.918	+3.[illegible]	1	2a	+	20.5	42.8	00 55 08	80.6	20	30

Np	ℓ	b	wt.	run	$\frac{db}{dt}$	alt.	az.	GCT	+	1/2wd	I_{rel}
11	126°085	+1°740	1	3a	–	24°5	48°	$01^h20^m20^s$	77°2	30°	25 mv.
	126.242	+1.285	1	1a	–	20.5	45.1	00 58 56	81.4	25	27
	127.812	+1.897	1	5a	–	16.6	42.5	00 25 45	83.8	29	20
12	128.687	+1.415	1	2a	–	16.6	43.9	00 43 43	83.1	17	25
	129.008	+0.610	1	4a	+	16.6	45	00 37 35	83.1	34	25
	129.685	+2.228	1	3a	+	20.5	48	01 17 34	77.8	33	22
	129.838	+1.977	1	1a	+	16.6	44.7	00 57 04	81.7	29	25
	130.970	+1,990	1	5a	+	12.8	42	00 20 15	84.7	26	20
	131.332	+1.370	1	4a	–	12.8	43	00 26 37	84.6	32	25
	131.822	+3.133	1	2a	+	12.8	42	00 39 51	83.4	15	25
	132.093	+1.128	1	3a	–	16.6	48	01 04 50	80.1	29	22
	132.345	+1.155	1	1a	–	12.8	44.4	00 46 08	83.6	26	25
	133.003	+0.083	1	5a	–	9.1	42	00 05 40	87.2	29	20
	134.265	+1.773	1	2a	–	9.1	42	00 28 31	85.4	15	25
	134.912	–0.628	1	4a	+	9.1	45	00 24 12	85.4	33	22

Np	ℓ	b	wt.	run	$\frac{db}{dt}$	alt.	az.	GCT	[illegible]	1/2wd	I_{rel}
12	135°.543	+1°.368	1	3a	+	12°.8	48°	$01^h02^m14^s$	80°.6	32°	20 mv.
	135.763	+1.537	1	1a	+	9.1	44.1	00 11 07	83.9	30	25
	135.863	+2.385	1	5a	+	5.5	39	00 00 20	87.7	25	20
	136.900	+0.677	1	4a	−	5.5	42	00 12 12	86.8	24	25
	137.628	+0.627	1	2a	+	5.5	43	00 25 51	86.0	20	25
	137.875	+2.633	1	1a	−	5.5	41.5	00 32 57	85.4	27	28
	137.912	+0.103	1	3a	−	9.1	48	00 51 00	82.3	29	22
	139.723	−3.267	0a	2a	−	2.0	45	00 13 21	87.9	24	25
	140.100	+0.450	0a	4a	+	2.0	42	00 09 35	87.2	30	25
	140.902	+2.062	1	3a	+	5.5	46	00 48 07	82.5	20	25
	141.290	+0.580	0a	1a	+	2.0	43.5	00 31 01	85.9	27	28
	143.283	−1.198	0a	3a	−	2.0	48	00 36 49	84.2	24	25
13	155.770	−2.758	1	3b	+	61.5	148.0	08 03 42	83.7	22	20
	156.030	−1.710	1	5b	−	61.5	146.3	07 57 25	85.4	19	18
	156.078	−1.835	1	1b	+	61.5	147.0	08 13 47	81.8	22	21

Ep	ℓ	b	wt.	run	$\frac{db}{dt}$	alt.	az.	GCT	[illegible]	1/2wd	I_{rel}
13	156°.080	−2°.512	1	4b	−	64°.5	148°.8	$08^h02^m40^s$	83°.2	24°	30 mv.
	157.980	−2.728	1	2b	−	64.5	161.1	08 34 51	74.2	26	21
	158.617	−1.923	1	3b	−	60.5	140.7	07 52 30	89.4	25	17
	158.863	−1.497	1	1b	−	60.5	140.7	08 02 27	89.5	24	15
	159.065	−2.233	1	5b	+	60.5	143.0	07 48 37	87.7	25	18
	159.438	−1.115	1	4b	+	60.5	142.0	07 55 35	88.8	27	30
	161.600	−1.800	1	3b	+	56.5	137.2	07 44 08	88.1	29	18
	161.717	−2.553	1	2b	+	60.5	155.8	08 28 47	78.6	25	18
	161.723	−1.640	1	5b	−	56.5	137.3	07 37 17	88.2	25	18
	161.808	−0.830	1	1b	+	56.5	136.2	07 53 57	88.8	23	14
	161.863	−1.333	1	4b	−	56.5	137.2	07 42 25	88.0	23	28
	164.038	−1.390	1	3b	−	52.5	132.6	07 32 22	85.0	27	16
	164.323	−1.363	1	1b	−	52.5	133.3	07 42 21	85.5	27	15
	164.562	−0.723	1	5b	+	52.5	133.0	07 28 45	85.1	26	16
	164.722	−0.503	1	4b	+	52.5	133.1	07 31 00	85.1	28	23

Np	ℓ	b	wt.	run	$\frac{db}{dt}$	alt.	az.	GCT	-|-	1/2wd	I_{rel}
13	165°.227	-1°.072	1	2b	-	56°.5	148°.3	$08^h 20^m 16^s$	84°.6	25°	19 mv.
	166.900	-1.475	1	3b	+	48.5	130.5	07 23 58	83.8	29	17
14	167.048	-1.442	1	5b	-	48.5	130.8	07 17 10	83.9	34	16
	167.102	-0.623	1	1b	+	48.5	129.9	07 33 57	83.2	30	15
	167.120	-0.435	1	4b	-	48.5	129.7	07 22 25	83.1	32	15
	168.637	-1.733	1	2b	+	52.5	146.8	08 14 45	85.7	27	17
	169.180	-0.862	1	3b	-	44.5	126.7	07 12 29	81.5	28	17
	169.520	-1.305	1	1b	-	44.5	127.9	07 22 13	82.2	32	14
	169.897	-1.570	1	5b	+	44.5	129.0	07 08 50	82.9	32	16
	169.960	-0.753	1	4b	+	44.5	128.2	07 13 55	82.3	30	15
	171.790	-2.482	1	2b	-	48.5	144.9	08 06 59	87.0	28	15
	171.877	-0.855	1	2b	-	44.5	132.5	07 35 13	84.9	26	15
	172.025	-1.302	1	3b	+	40.5	125.6	07 04 03	81.0	30	18
	172.082	-0.613	1	5b	-	40.5	125.0	06 57 15	80.6	32	14

Ep	ℓ	b	wt.	run	$\frac{db}{dt}$	alt.	az.	GCT	⌒|⌒	1/2wd	I_{rel}
14	172°.255	−0.768	1	1b	+	40°.5	125°.5	$07^h 14^m 00^s$	80°.9	31°	14 mv.
	172.267	−0.840	1	4b	−	40.5	125.6	07 02 13	80.9	30	14
	174.210	−1.168	1	3b	−	36.5	122.9	06 52 07	79.6	35	16
	174.690	−1.952	1	1b	−	36.5	124.5	07 02 11	80.4	33	15
	174.955	−1.243	1	5b	+	36.5	124.3	06 48 56	80.3	27	12
	175.205	−1.707	1	4b	+	36.5	125.2	05 54 00	80.8	31	15
	175.243	−2.193	1	2b	+	40.5	133.1	07 29 36	85.3	23	13
	177.023	−0.642	1	5b	−	32.5	121.2	06 37 00	78.6	31	10
15	177.207	−2.217	1	3b	+	32.5	122.9	06 44 07	79.6	30	16
	177.380	−1.327	1	4b	−	32.5	122.4	06 42 20	79.3	34	15
	177.547	−2.352	1	1b	+	32.5	123.6	06 54 00	79.9	30	15
	178.033	−1.573	1	2b	−	36.5	130.4	07 21 10	83.6	34	13
	179.055	−0.800	1	3b	−	28.5	119.0	06 32 04	77.6	32	16
	179.102	−0.755	1	1b	−	28.5	119.5	06 42 05	77.3	28	14
	179.623	−1.910	1	2b	+	32.5	126.8	07 04 04	81.5	33	13

Np	ℓ	b	wt.	run	$\frac{db}{dt}$	alt.	az.	GCT	—|—	1/2wd	I_{rel}
15	179°.978	−1°.157	1	5b	+	28°.5	121°.0	$06^h29^m00^s$	78°.5	27°	14 mv.
	180.138	−0.910	1	2b	−	28.5	120.8	06 42 29	78.4	32	13
	180.357	−2.513	1	4b	+	28.5	122.5	06 34 00	79.2	32	14
	182.147	−2.120	1	3b	+	24.5	119.5	06 24 14	77.7	28	16
	182.203	−0.748	1	1b	+	24.5	118.5	06 34 17	77.3	34	15
	182.238	−2.068	1	5b	−	24.5	119.6	06 17 00	77.7	32	14
	182.293	−1.333	1	4b	−	24.5	119.1	06 22 15	77.5	30	13
	183.033	−1.562	1	2b	+	24.5	120.1	06 34 18	78.1	33	13
	183.935	−0.942	1	3b	−	20.5	116.2	06 12 04	76.2	34	14
	184.475	−1.645	1	1b	−	20.5	117.5	06 22 07	76.7	29	13
	184.933	−0.642	1	2b	−	20.5	117.4	06 22 18	76.7	24	13
	185.098	−2.432	1	5b	+	20.5	119	06 09 00	77.2	—	14
	185.113	−1.615	1	4b	+	20.5	118.4	06 14 10	77.1	27	12
16	186.683	−1.290	1	3b	+	16.6	115.7	06 04 08	75.8	30	18
	187.070	−2.338	1	5b	−	16.6	117	05 57 00	76.2	—	14

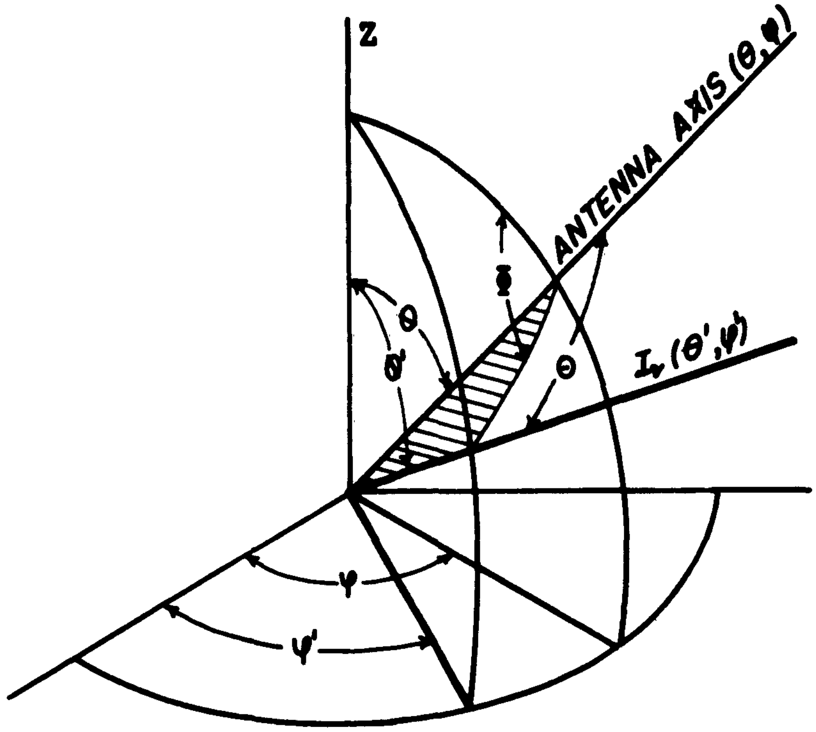
Np	ℓ	b	wt	run	$\frac{db}{dt}$	alt.	az.	GCT	ψ	1/2wd	I_{rel}
16	187°100	-0°505	1	4b	-	16°6	115°7	$06^h 03^m 46^s$	75°9	28°	14 mv.
	187.282	-2.072	1	1b	+	16.6	117.1	06 14 23	76.2	29	13
	187.943	-2.038	1	2b	+	16.6	118.0	06 14 25	76.6	22	13
	188.117	-2.158	1	1b	-	12.8	115.3	06 02 02	75.3	31	13
	189.410	-2.732	1	3b	-	12.8	116.1	05 55 00	75.5	32	18
	189.645	-2.420	1	5b	+	12.8	116.2	05 49 00	75.6	26	14
	189.833	-1.782	1	2b	-	12.8	116.0	06 02 50	75.6	30	17
	190.498	-1.512	1	4b	+	12.8	116.7	05 59 15	75.9	28	14
	191.383	-2.395	1	5b	-	9.1	114.4	05 36 55	74.6	38	16
	192.072	-1.377	1	2b	+	9.1	114.6	05 54 17	74.9	31	17
	192.192	-4.030	1	1b	+	9.1	116.6	05 54 47	75.0	26	18
	192.932	-2.053	1	4b	-	9.1	116.2	05 50 20	75.3	29	14
	192.932	-6.208	1	3b	+	9.1	119.1	05 47 52	75.4	32	20
	193.028	+0.152	1	5b	+	5.5	111	05 29 10	73.8	39	20
	193.282	-2.433	1	1b	-	5.5	113.1	05 42 00	73.8	27	18

Np	ℓ	b	wt.	run	$\frac{db}{dt}$	alt.	az.	GCT	-|-	1/2wd	I_{rel}
16	194°355	-3°248	1	3b	-	5°5	115°0	$05^h 39^m 00$	74°2	38°	20 mv.
	194.472	-2.592	1	2b	-	5.5	114.7	05 41 41	74.3	41	21
	195.772	-1.628	1	4b	+	5.5	115.7	05 45 47	74.9	27	16
	196.033	-3.998	0a	1b	+	2.0	114.0	05 34 20	73.2	38	18
	196.558	-3.280	0a	2b	+	2.0	114.2	05 31 40	73.5	42	21
	197.157	-3.318	0a	3b	+	2.0	115	05 34 10	73.7	38	24
	198.307	-3.115	0a	4b	-	2.0	116.3	05 37 05	74.2	38	20

APPENDIX II

Coordinates and Weights of the Normal Points

No.	Weight	Galactic Longitude	Galactic Latitude	No.	Weight	Galactic Longitude	Galactic Latitude
1	19	331.194	-1.617	9	19	87.204	0.325
2	20	340.600	-1.520	10	19	107.112	1.949
3	20	350.814	-0.953	11	20	122.070	1.883
4	18	0.880	-1.358	12	20	133.817	1.381
5	20	11.921	-2.141	13	20	160.820	-1.652
6	19	25.195	-0.659	14	20	171.604	-1.224
7	19	44.369	1.590	15	20	181.210	-1.546
8	20	66.256	0.568	16	20	190.800	-2.235



SPHERICAL COORDINATES

FIG. 1

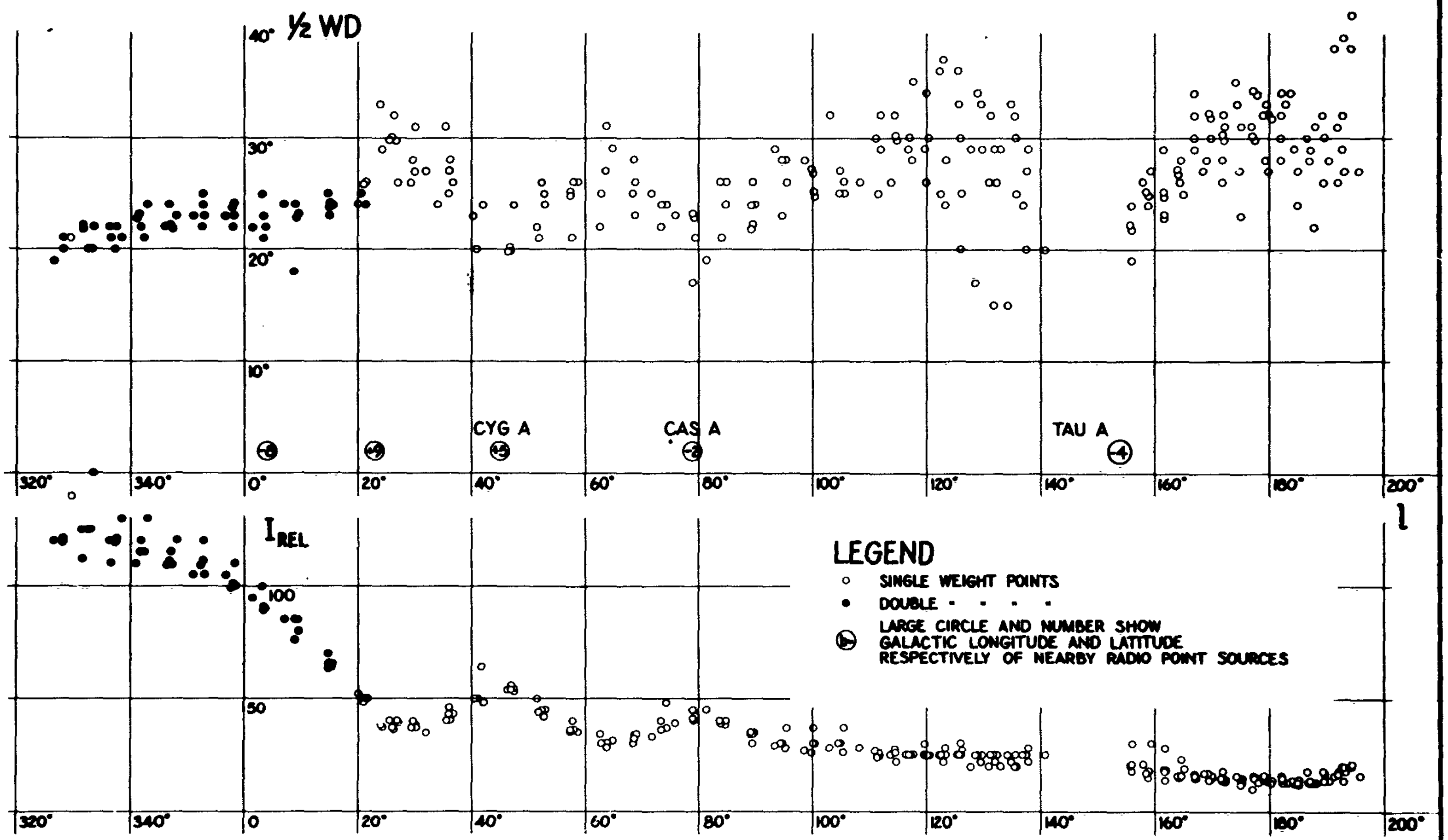


FIG. 2 APPARENT HALF-WIDTH AND RELATIVE INTENSITY OF 205 MC. RADIO RADIATION VS. GALACTIC LONGITUDE

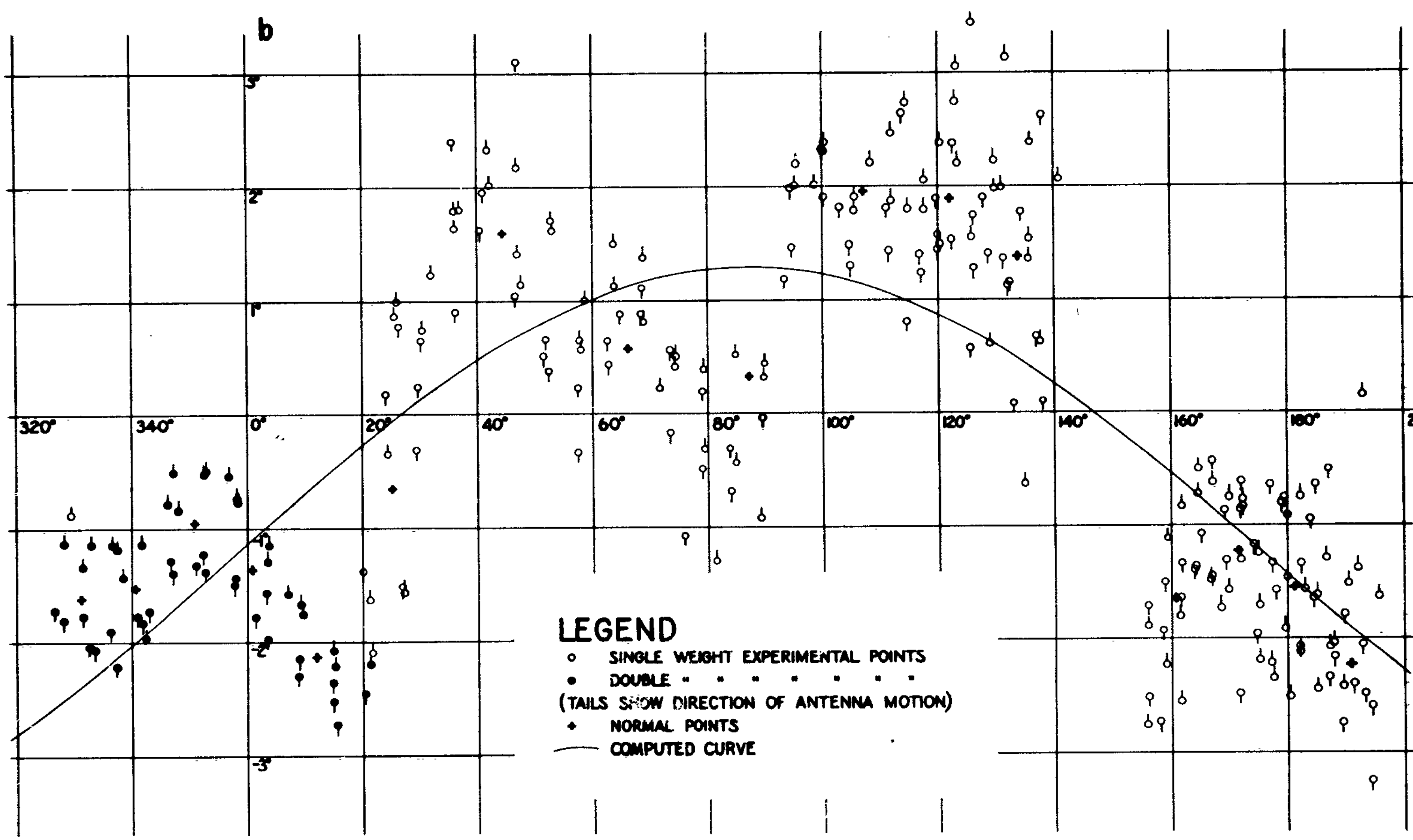


FIG. 3 POSITIONS OF INDIVIDUAL SWEEP MAXIMA (1948 I.A.U. GALACTIC COORDINATES)

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